1. Do Excercise 4, LED driver, in the GPIO handout (download from course website).

   Note: The ESP32 datasheet recommends limiting GPIO currents to 6mA per pin. If you connect an LED to the ESP32, you may want to use a larger resistor than the one calculated in this assignment to stay within the recommended limit.

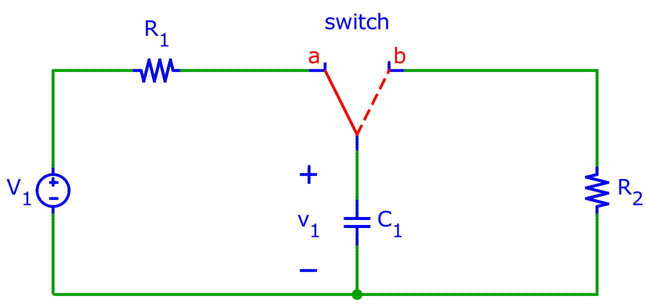
2. (D-56) In this problem, you design a timer. The switch in the diagram shown below is initially in position a. When the capacitor voltage v_1 reaches $V_H = \frac{3}{4}V_1$, the switch changes to position b. It reverts back to position a when v_1 drops below $V_L = \frac{1}{4}V_1$ and the cycle repeats.

   For $C_1 = 6.9\,\text{mF}$ Determine the values of R_1 and R_2 such that the switch remains in position a for 2.7 s and position b for 6.3 s. Timer circuits such as the popular "555 IC" operating on this principle use an electronic switch (consisting of transistors) that also controls an associated device, e.g. a light.

   Note that initially v_1 starts from 0 V (or whatever voltage was stored on C_1 when the circuit was powered on). Because of this, the first cycle may be longer than later ones, which will all be of equal duration. Ignore this initial transient (the first cycle) when determining the resistor values.

   $R_1 =$ ☐

   $R_2 =$ ☐



3. (D-64) Shown below is a touch sensor consisting of capacitance C_1 with nominal value 4.9 pF that increases by 20 % when touched by a finger, resistor R_1 =500 kΩ and a microcontroller with digital ports A and B. Touch is detected by measuring the change of the charging and/or discharging time of C_1 through R_1.

   To measure the discharging time T_1, ports A and B are first set as outputs. A is driven to V_{dd}, and B is driven to V_{ss}. Then A is reconfigured as an input, resulting in $v_a(t)$ to decrease exponentially from V_{dd} to V_{ss}=0 V. The microcontroller measures the time T_1 for $v_a(t)$ to reach $V_{th} = rV_{dd}$, i.e. $v_a(T_1) = V_{th}$.

   Suggestion: sketch $v_a(t)$ before answering the questions below.

no finger	$r = 50\,\%$	$T_1 =$	☐
with finger	$r = 50\,\%$	$T_1 =$	☐
no finger	$r = 60\,\%$	$T_1 =$	☐
with finger	$r = 60\,\%$	$T_1 =$	☐

   As expected, the discharging time T_1 increases when a finger is present, but the change is an even stronger function of the threshold voltage V_{th}. In practice, this voltage varies randomly from device to device (i.e. one microcontroller you purchase may have $V_{th} = 0.57V_{dd}$, the next one has a different $V_{th} = 0.42V_{dd}$, etc.). The threshold V_{th} is also a function of temperature, leading to further variations. Because of this, its is impossible to build a reliable touch sensor based only on measuring the discharging time T_1.

The problem arising from varying V_{th} can be reduced significantly by basing the measurement on the sum of the discharging time T_1 and the charging time T_2. The charging time T_2 is measured by first setting $v_a = v_b = 0\,\text{V}$, followed by rising v_b to V_{dd}. T_2 is the time it takes $v_a(t)$ to reach V_{th}. Calculate T_2 and fill in the table below:

no finger	$r = 50\,\%$	$T_1 + T_2 =$	
with finger	$r = 50\,\%$	$T_1 + T_2 =$	
no finger	$r = 60\,\%$	$T_1 + T_2 =$	
with finger	$r = 60\,\%$	$T_1 + T_2 =$	

Now the variation due to changing V_{th} is much smaller than the change due to the presence of a finger, enabling reliable operation.